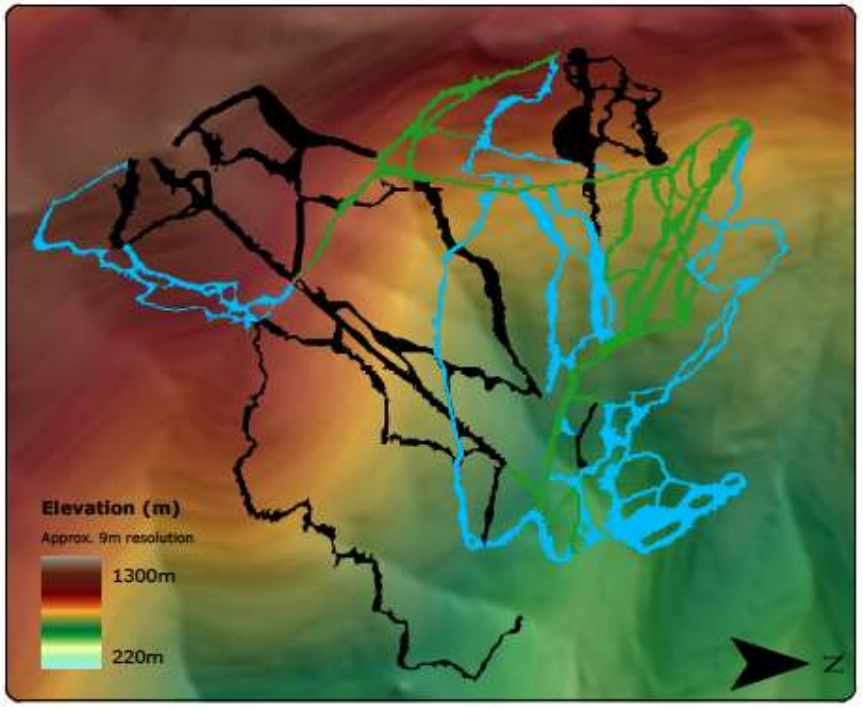
Circles (●) and Squares (■) and Diamonds (◆), Oh My!

A Comparison of Ski Trails Around the U.S.

Will Ouimet and Andy Anderson
Amherst College

Northeast Arc Users Conference
May 11th, 2010

Excerpt from **Geology 36: The Geological and Environmental Analysis of Landscapes**



Students: **Lindsay Barbieri, Sam Bell, Joe Black, Ben Bresler, Michael Buckler, Sarah Farron, Dan Freilich, Alex Gonzalez, Andy Greenspon, Laura Huober, Dan Kekacs, Ben Klein, Ted Lichtenberger, Tom Sibley, Rebecca Siegel, Cianna Wyshnytzky**

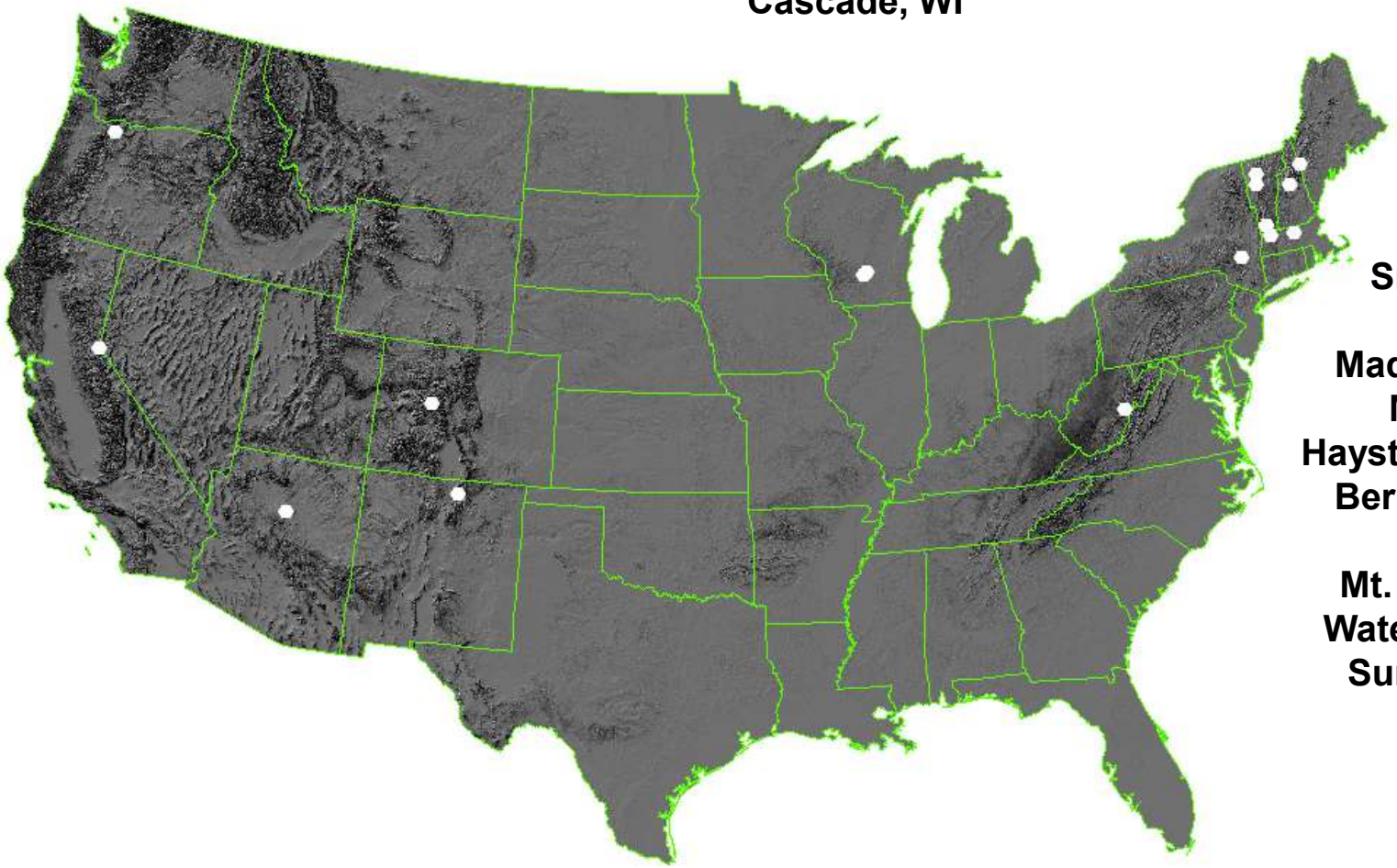
ASSIGNMENT FOR STUDENTS: Ski resorts across the country use a standard system to describe the increasing difficulty of their slopes: green circles, blue squares, black diamonds. But how do they really compare? What ski mountain will have the steepest trails, on average? Which ski mountains tend to underrate their trails, which tend to overrate their trails?

GIS Task: Use your GIS skills to link ski trails on a given mountain to slope angles measured from a Digital Elevation Model (DEM). Find and download all necessary data.

Ski Mountains of their choice
…all over the U.S…

WEST
Mt. Hood Meadows, OR
Heavenly, CA
Snowbowl, AZ
Buttermilk, CO
Taos, NM

CENTER
Devil's Head, WI
Cascade, WI



EAST
Snowshoe, WV
Hunter, NY
Mad River Glen, VT
Mt. Snow, VT
Haystack Mountain, VT
Berkshire East, MA
Stowe, VT
Mt. Wachusett, MA
Waterville Valley, NH
Sunday River, ME

Data

Trail Maps

Mad River Glen, VT

Mt. Snow, VT

Data

Mad River Glen, VT

Trail Maps

Ortho Imagery

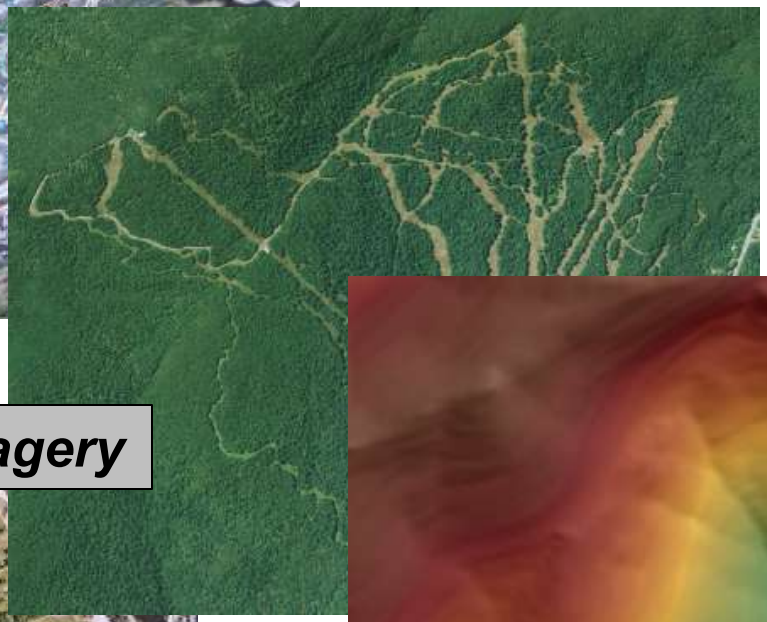
Mt. Snow, VT

Downloaded from:
seamless.usgs.gov

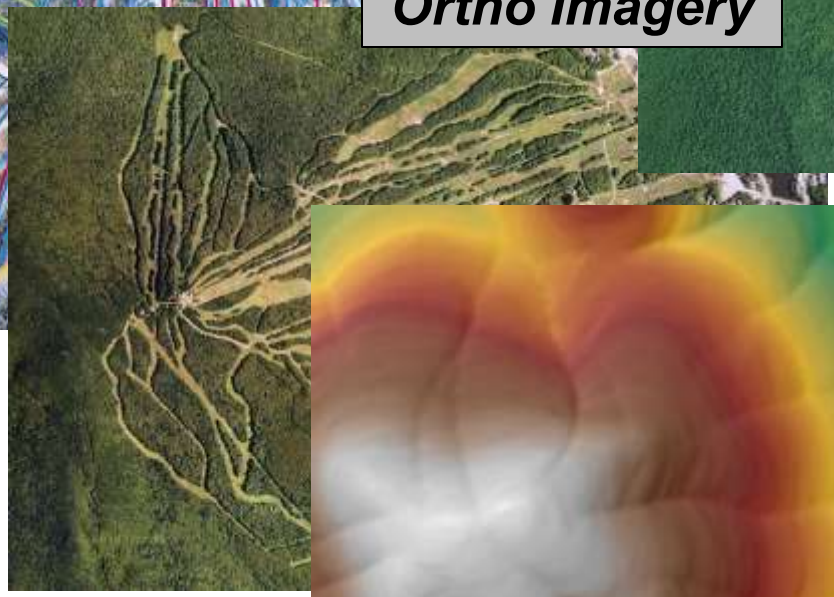
Data

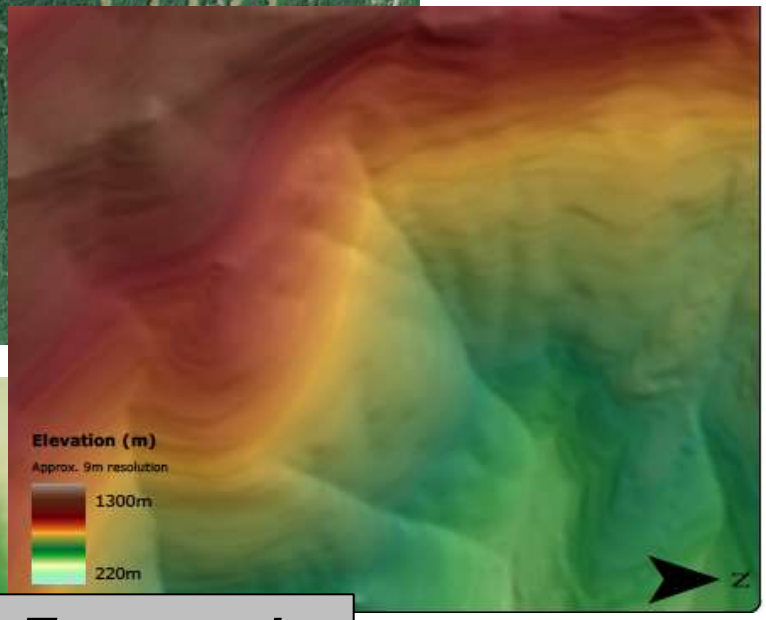
Mad River Glen, VT

Trail Maps

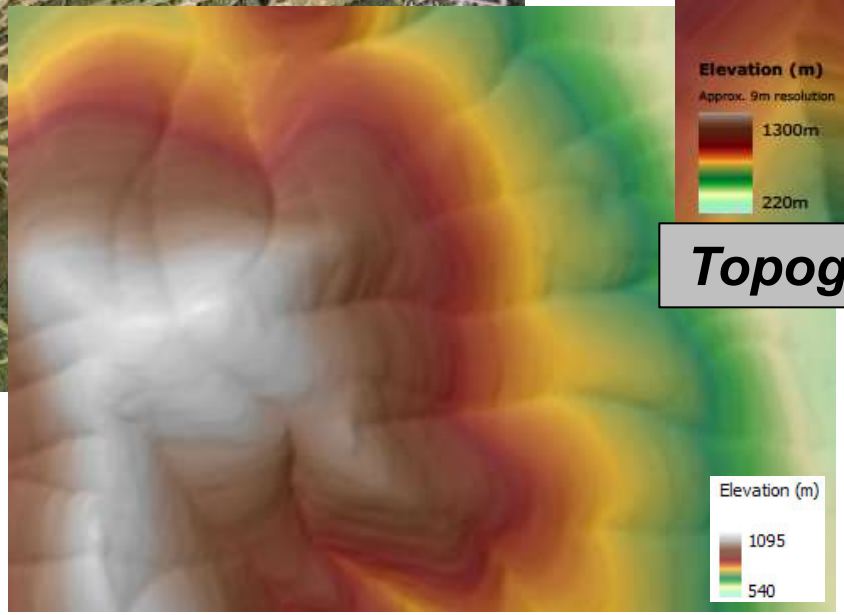


Ortho Imagery





Topography



Mt. Snow, VT

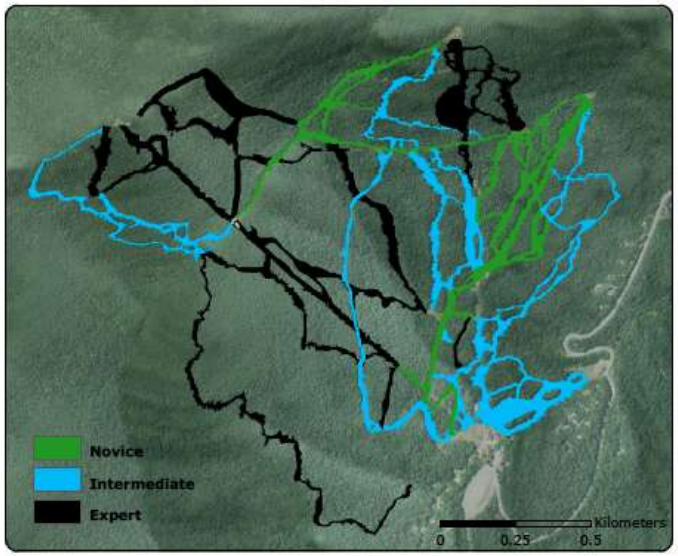
Downloaded from:
seamless.usgs.gov

Methods: Digitizing Trails

Combine Ortho-Imagery and Trail Maps

Methods: Digitizing Trails

(1) Raster Classification



Mad River Glen, VT

Combine Ortho-Imagery and Trail Maps

Methods: Digitizing Trails

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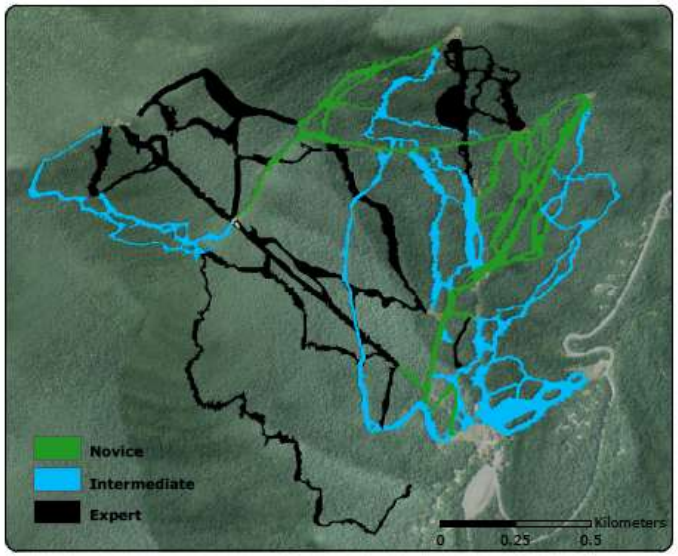
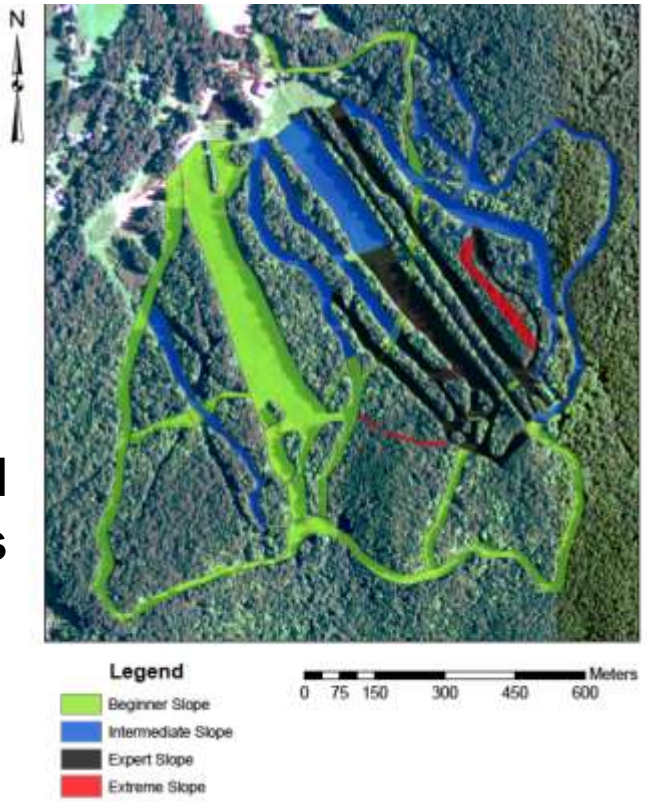


Mad River Glen, VT

Combine Ortho-Imagery and Trail Maps

(2) Digitized Polygons



Berkshire East, MA

Methods: Digitizing Trails

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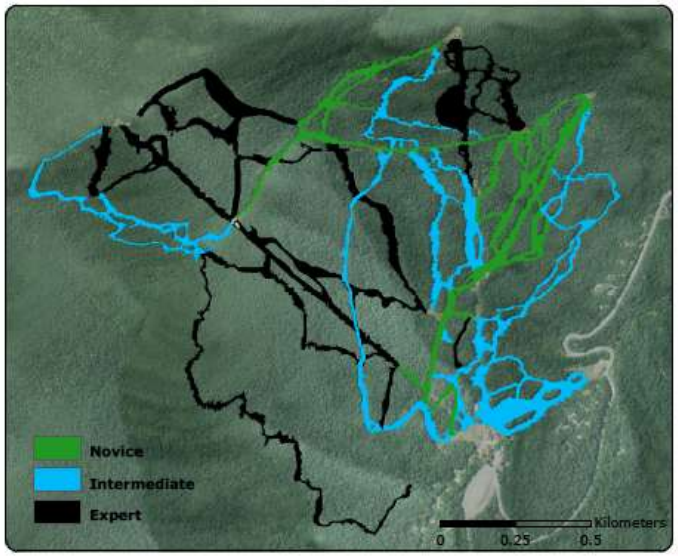

Mad River Glen, VT

Combine Ortho-Imagery and Trail Maps

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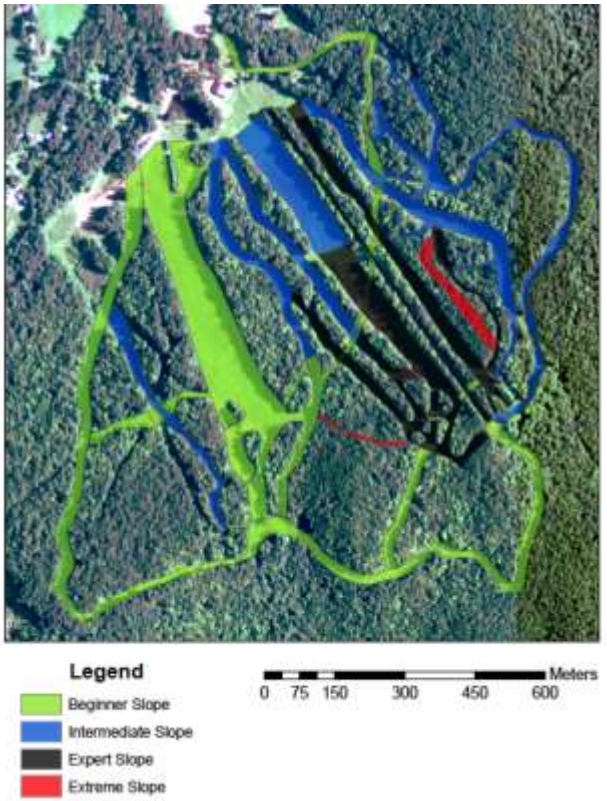
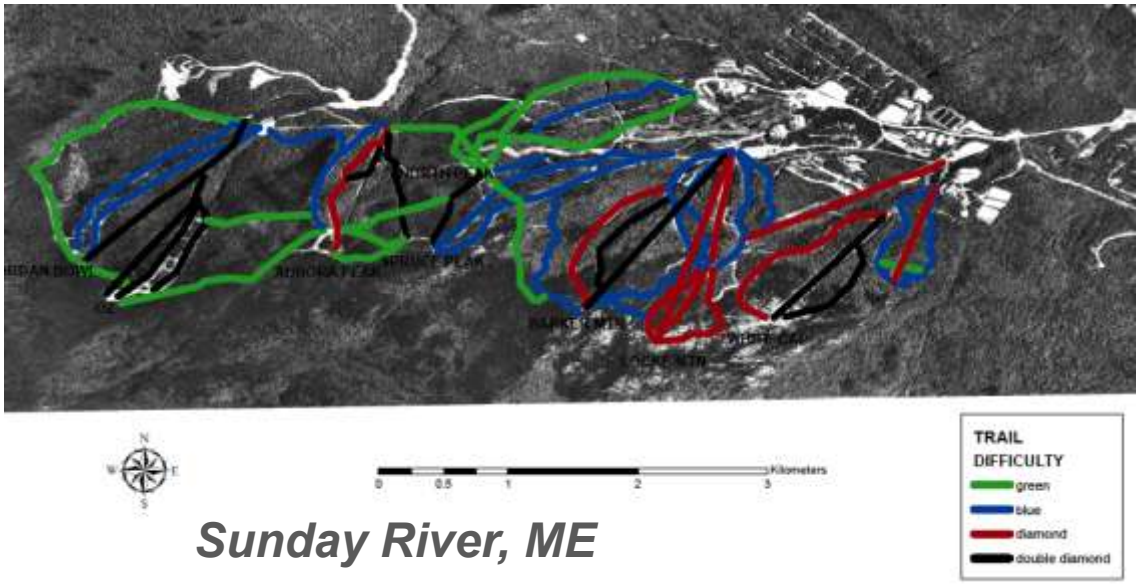


Berkshire East, MA

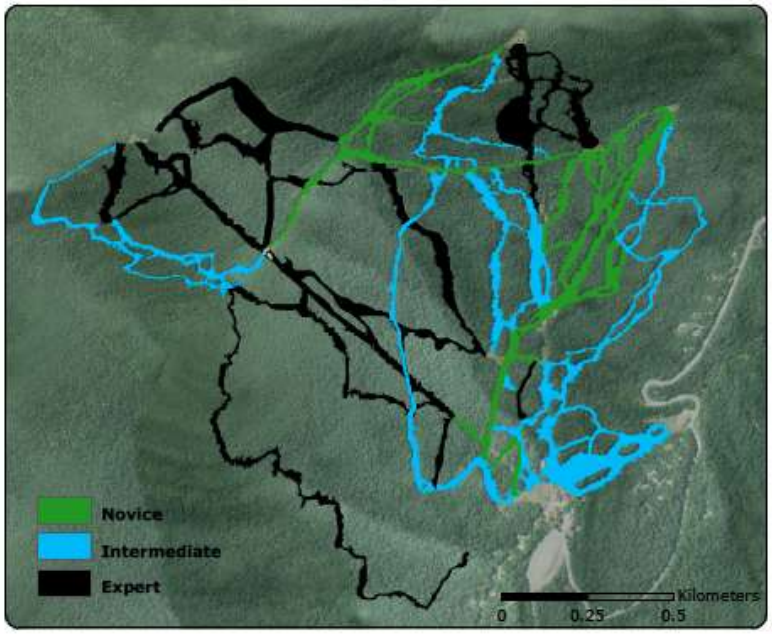
(3) Digitized Polylines

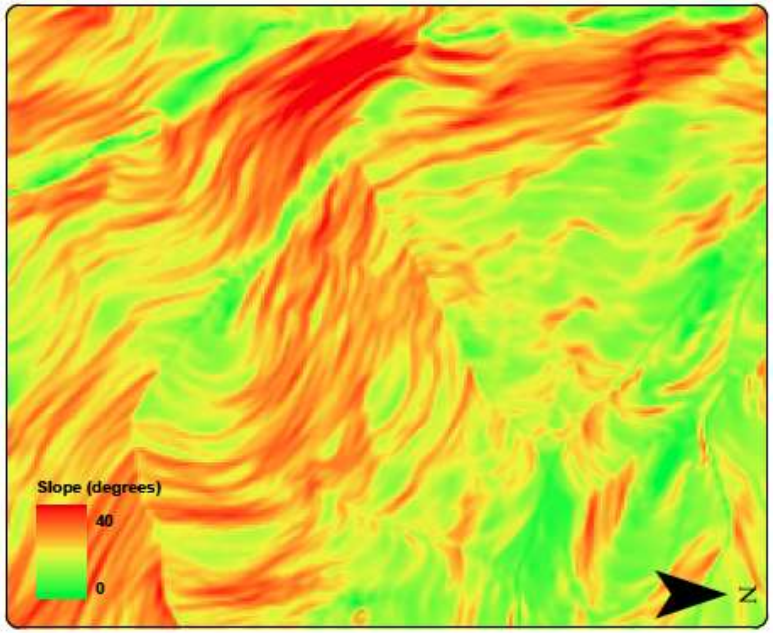


Sunday River, ME

Pros/Cons: Width of Trails, Imagery and DEM Resolution…

Methods: Slope Statistics…



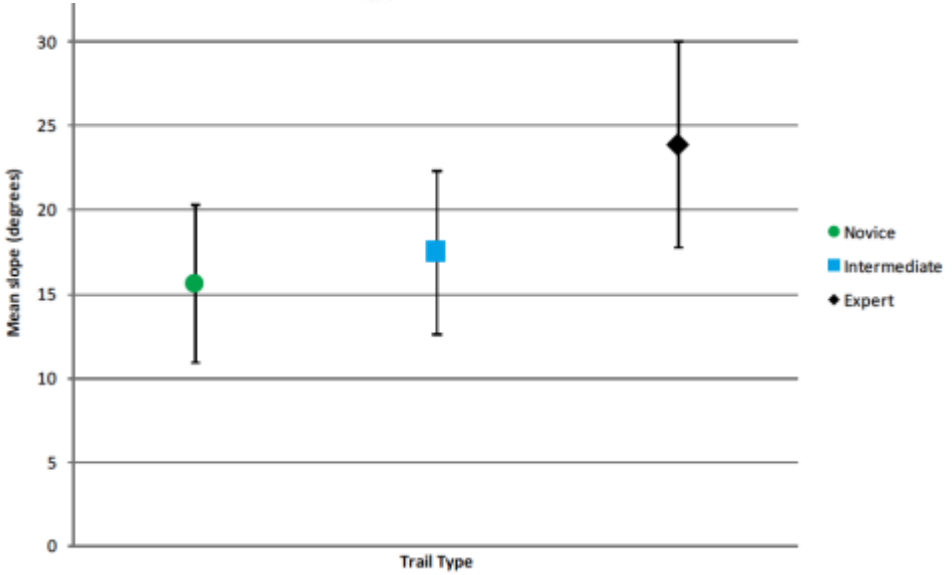


Zonal Statistics using Trail Shapefiles and ArcGIS Slope Map (slopes based on 3 x 3 cell neighborhoods)…

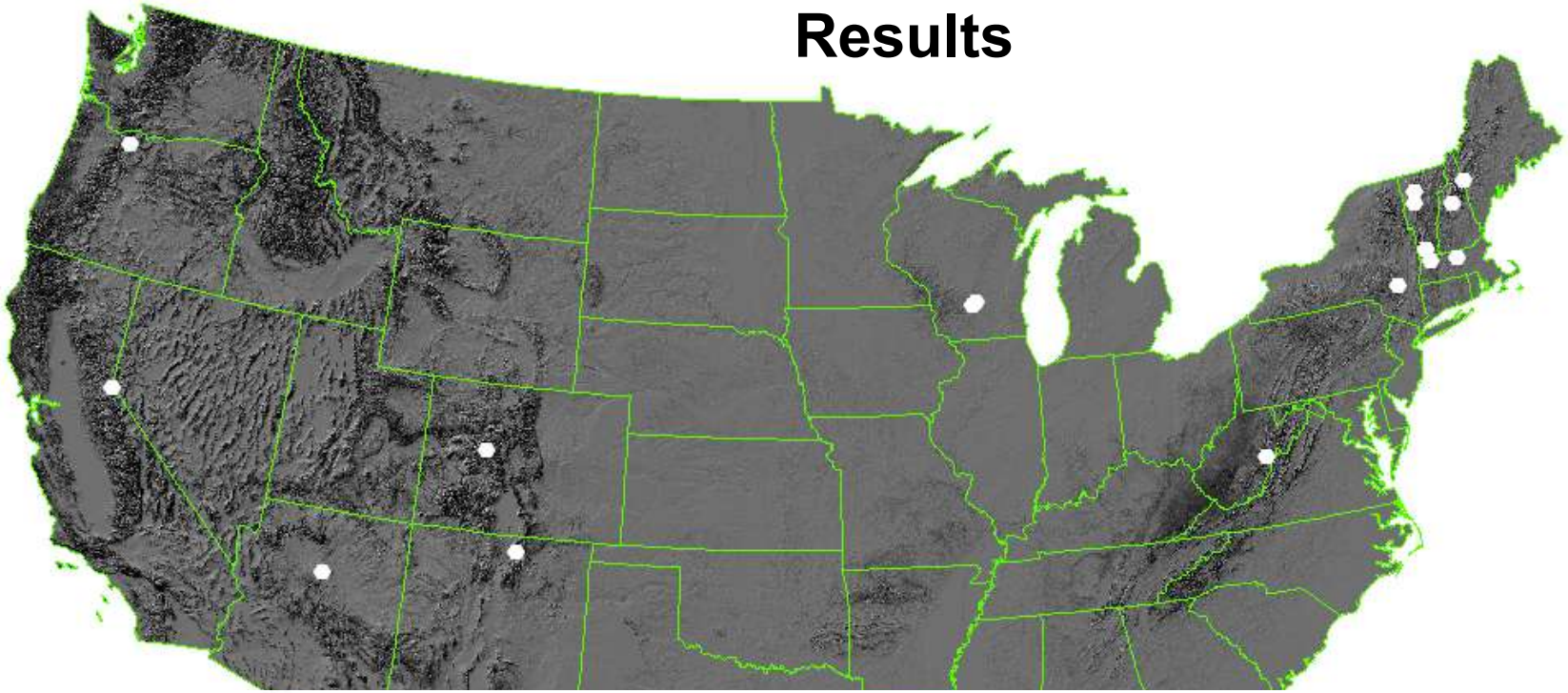
…Statistics for all pixels underneath trail types…

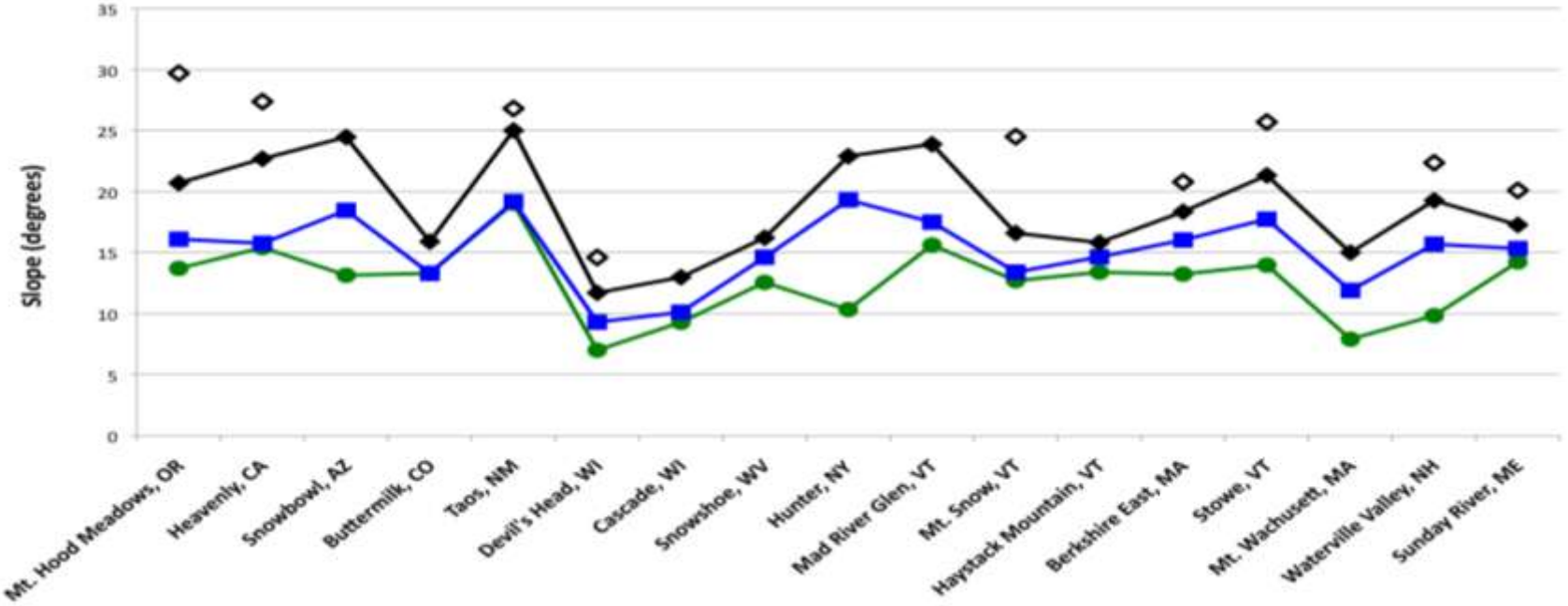
Mad River Glen, VT

	MEAN	MIN	MAX	STD DEV
Novice	15.62	6.08	35.93	4.70
Intermediate	17.50	2.57	31.94	4.86
Expert	23.88	1.51	38.64	6.12

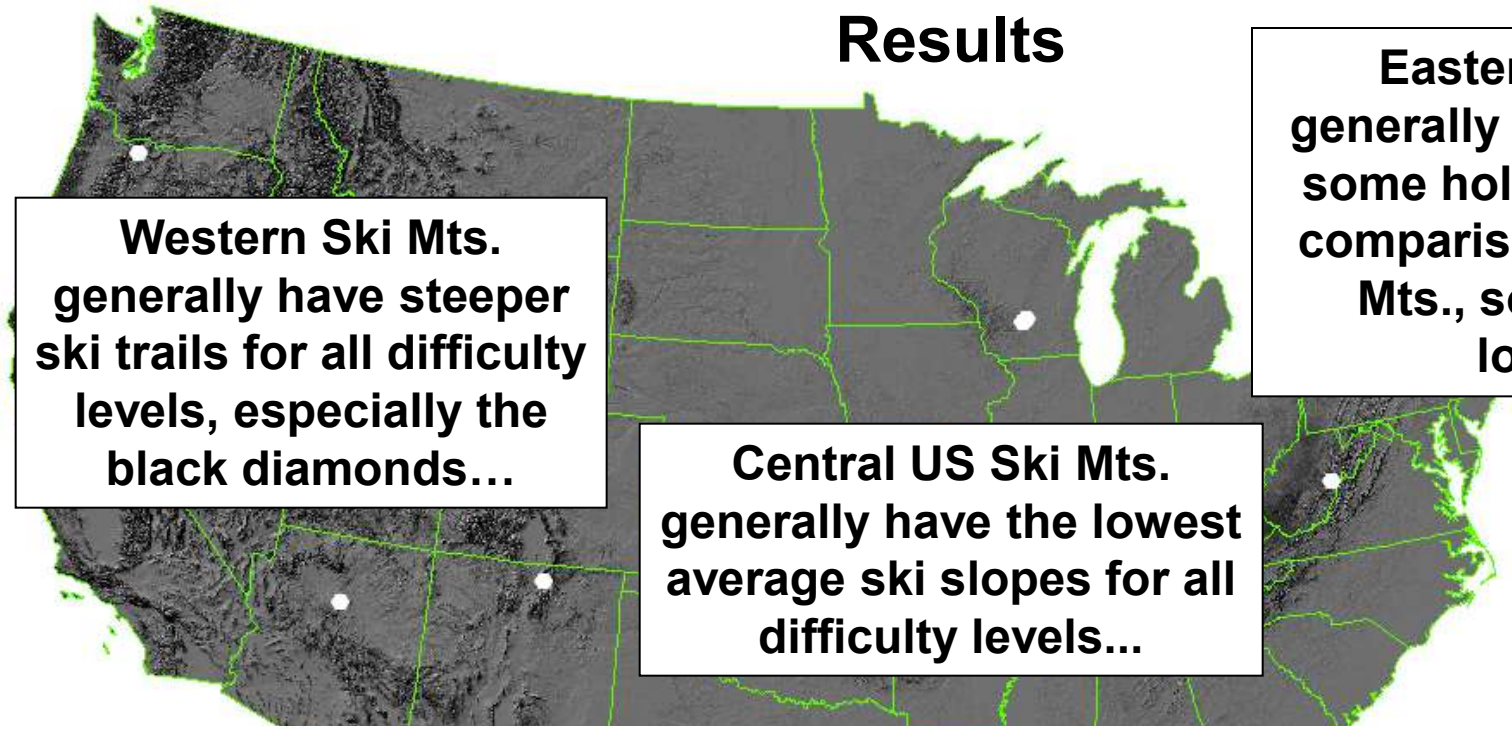


Results




Slope (degrees)
35
30
25
20
15
10
5
0
Mt. Hood Meadows, OR
Heavenly, CA
Snowbowl, AZ
Buttermilk, CO
Taos, NM
Devil's Head, WI
Cascade, WI
Snowshoe, WV
Hunter, NY
Mad River Glen, VT
Mt. Snow, VT
Haystack Mountain, VT
Berkshire East, MA
Stowe, VT
Mt. Wachusett, MA
Waterville Valley, NH
Sunday River, ME

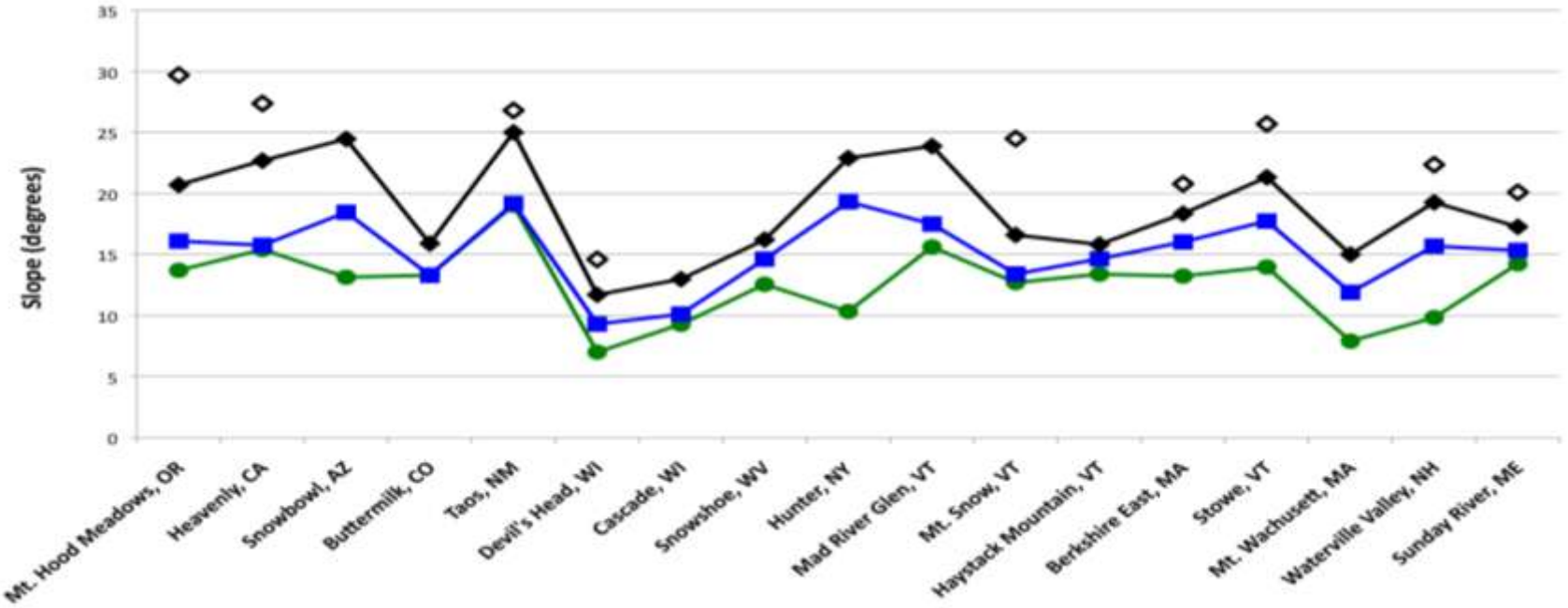
Results



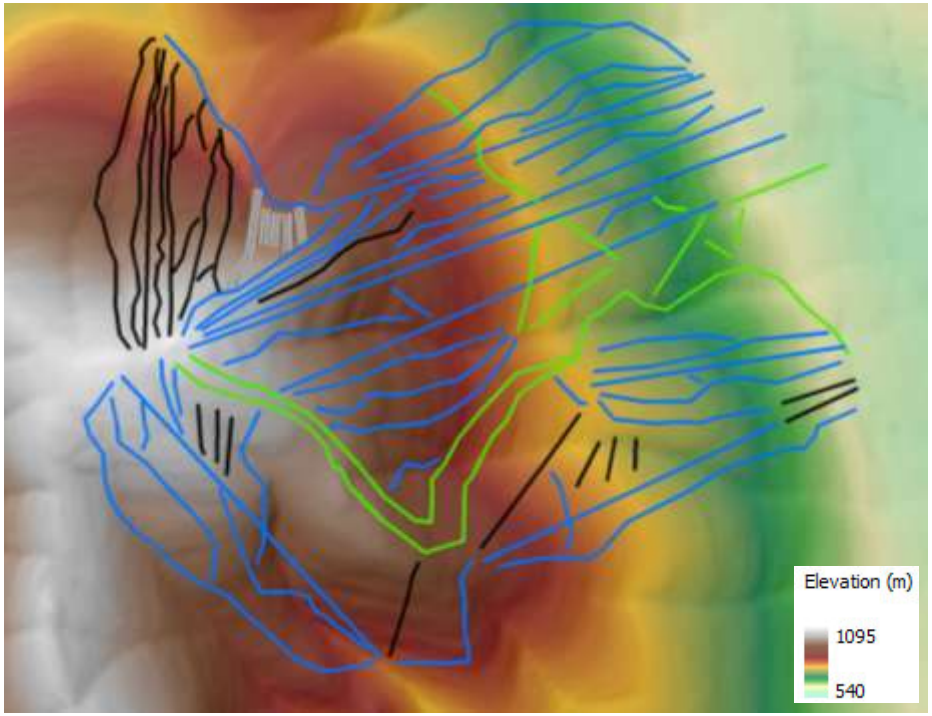
Western Ski Mts. generally have steeper ski trails for all difficulty levels, especially the black diamonds…

Central US Ski Mts. generally have the lowest average ski slopes for all difficulty levels...

Eastern Ski Mts. generally more variable, some hold their own in comparison to Western Mts., some clearly lower…



Alternative Method for Slope Calculation…



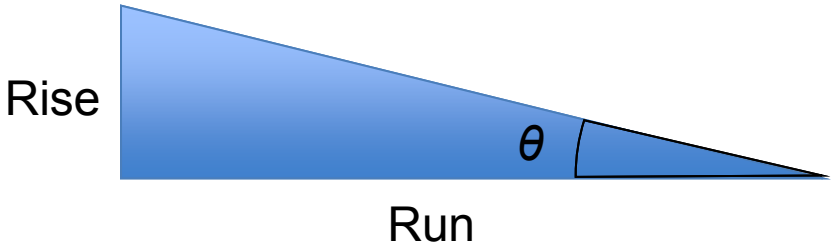
Mt. Snow, VT

Simpler approach…

For all trails, compare overall vertical drop (its rise) with its total horizontal length (its run)…

…Calculate average 'trail length' slopes for all trail types…

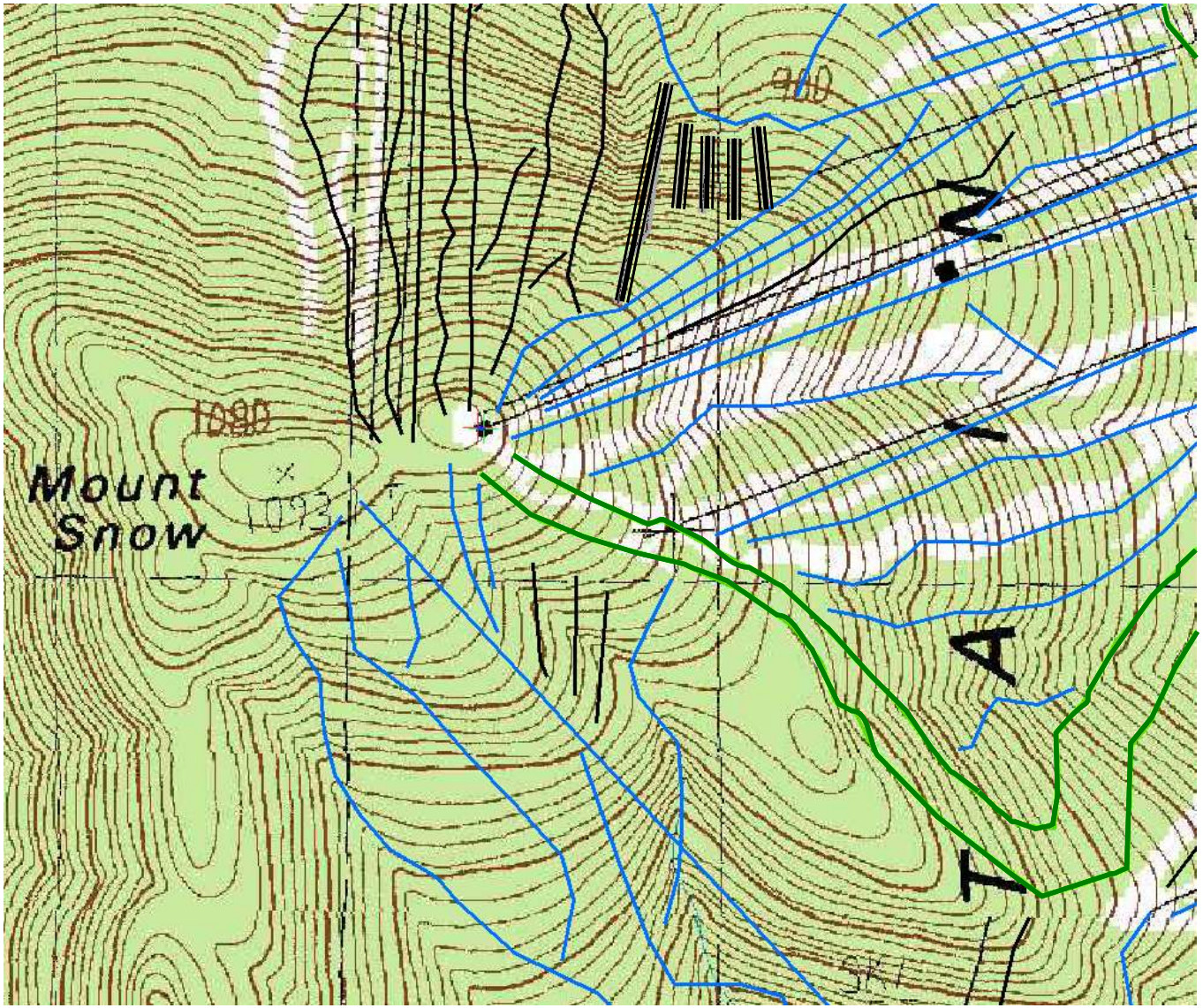
****Note that this only makes sense if the trail has a consistent decrease, which is usually the case for downhill skiing.**



Why the Different Slope Method?

Hard trails tend to go 'straight down', cutting across contours and paralleling local slopes…

- Easy
- Medium
- Hard
- Hardest

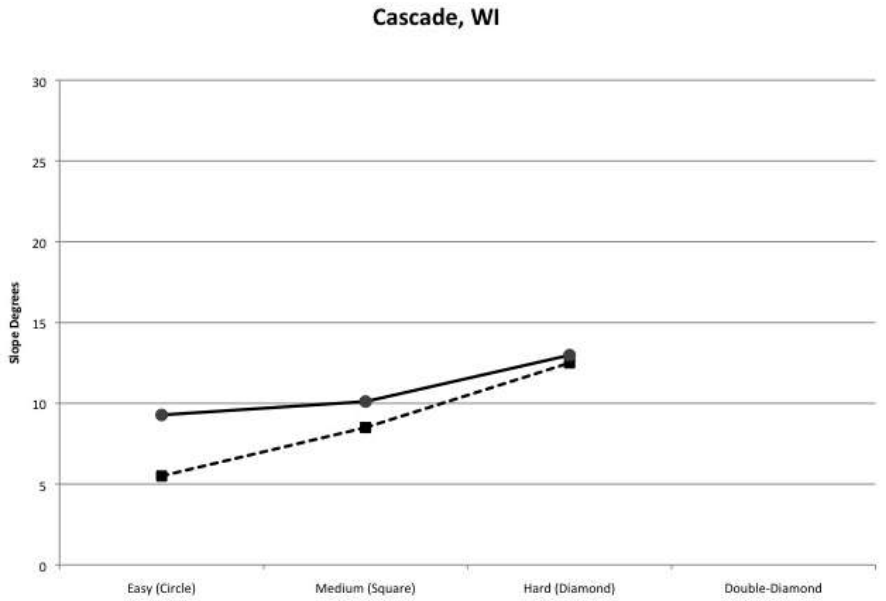


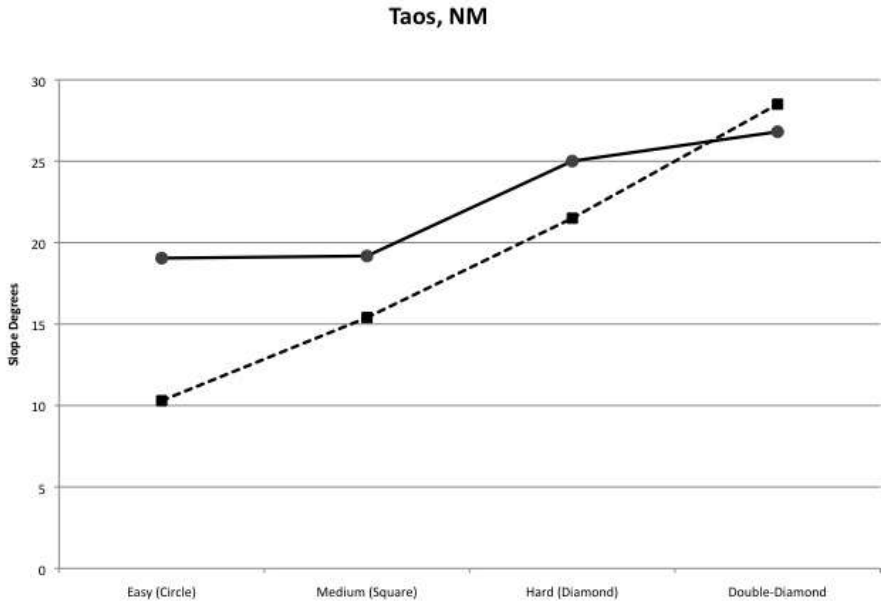
Easy trails tend to 'contour' more and may be parallel to or completely offset from local slopes, depending on the value…

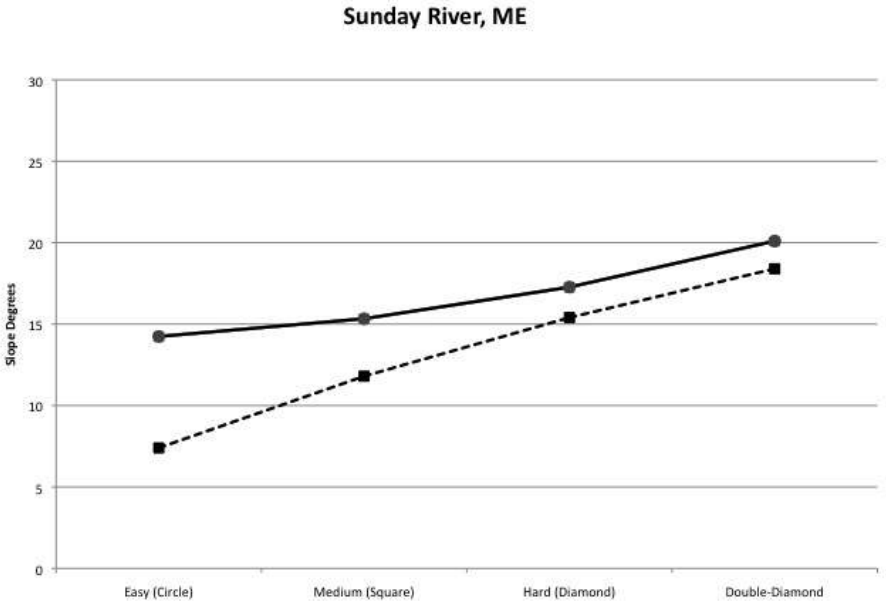
Results

Zonal, Slope Pixel Averaging Approach (solid) vs. Trail Rise/Trail Length Approach (dashed)

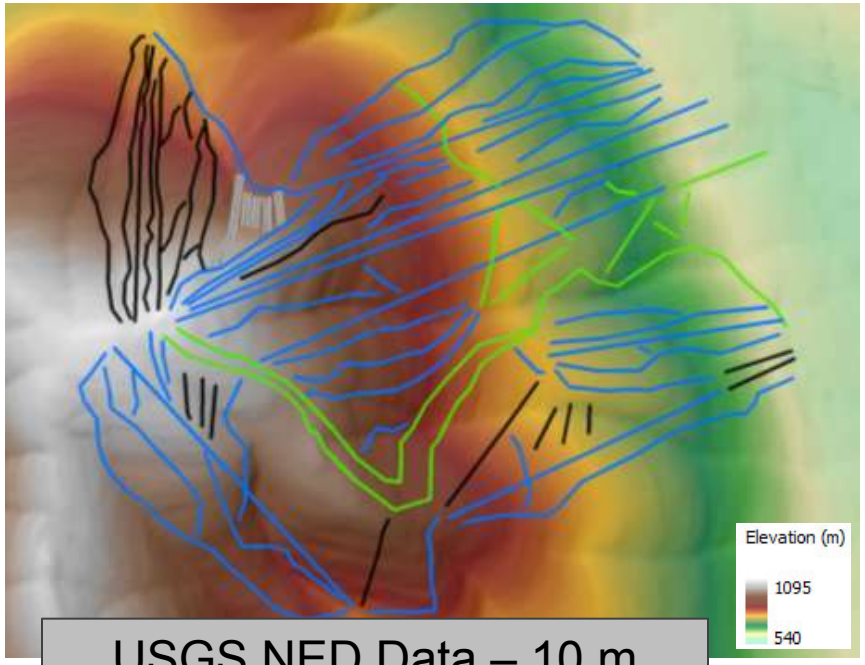
…As expected, the difference decreases with difficulty (i.e. it becomes more straight downhill)



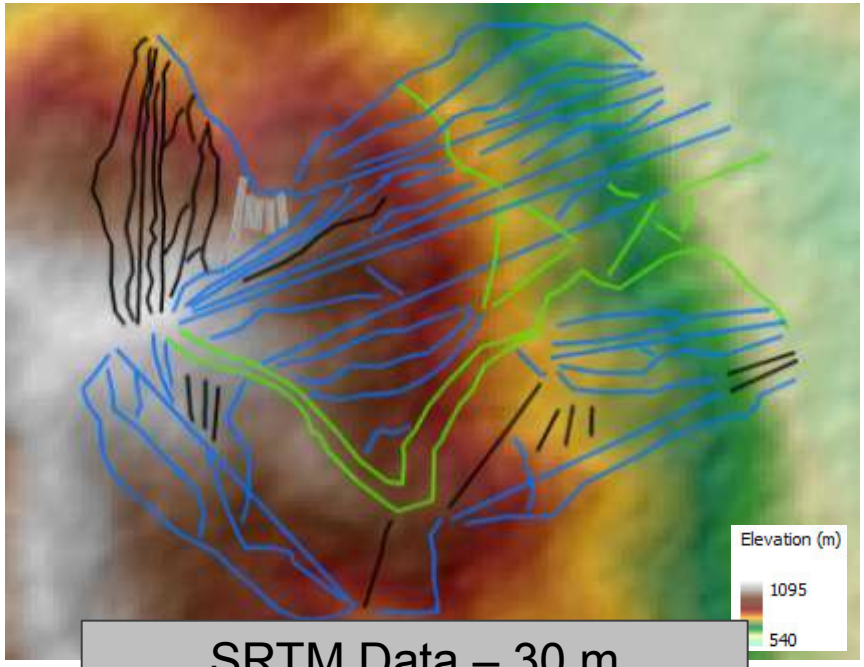




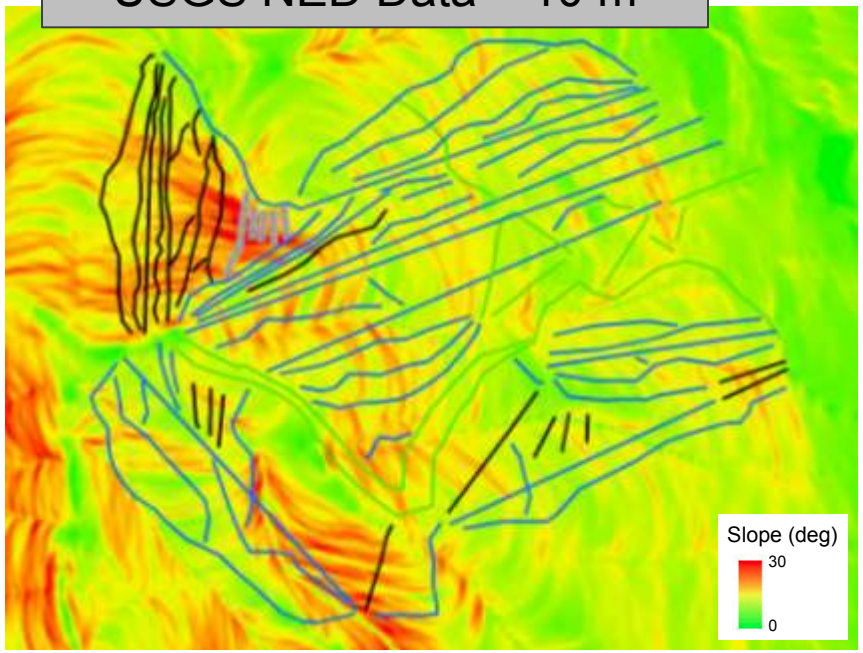
Effect of DEM Source and Resolution…

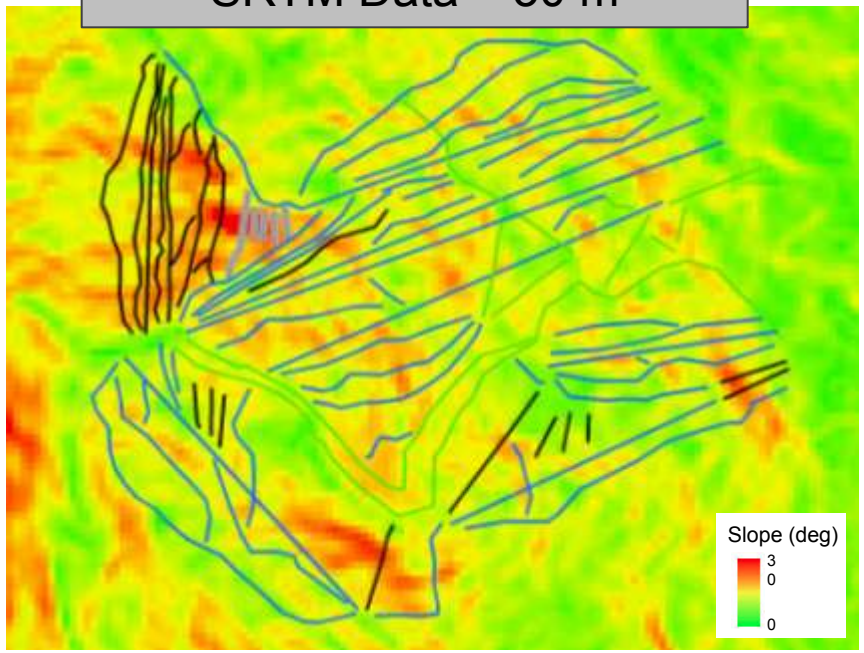


USGS NED Data – 10 m



SRTM Data – 30 m





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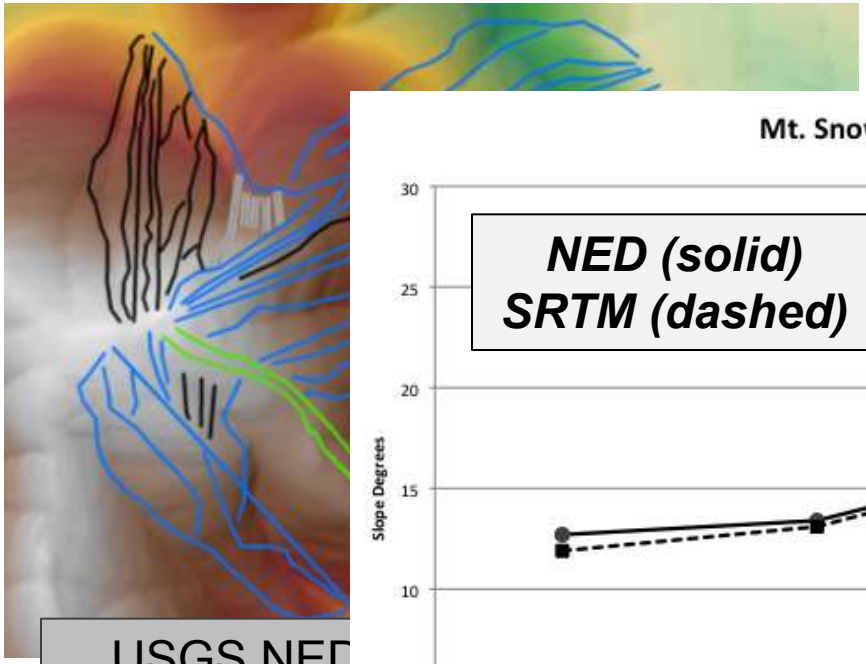
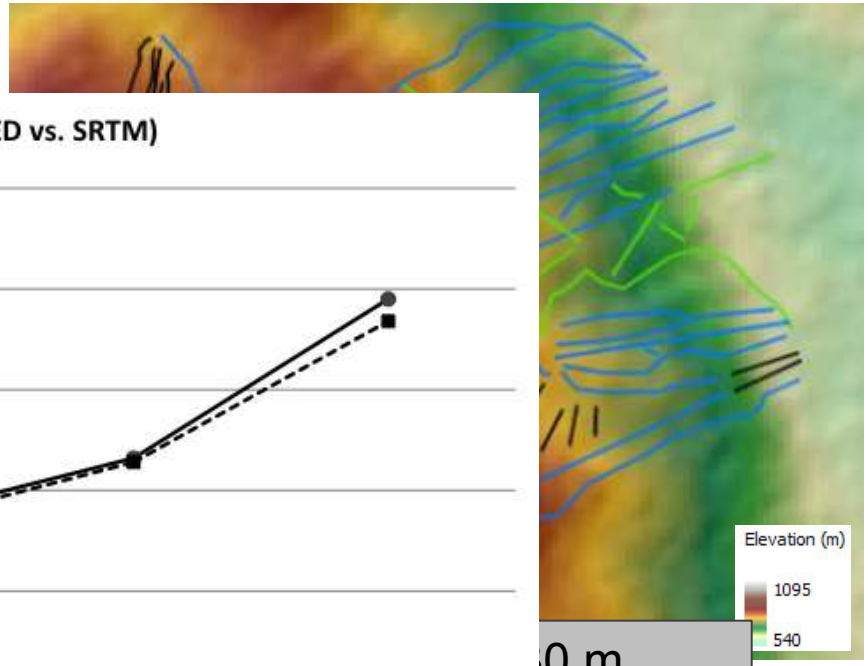
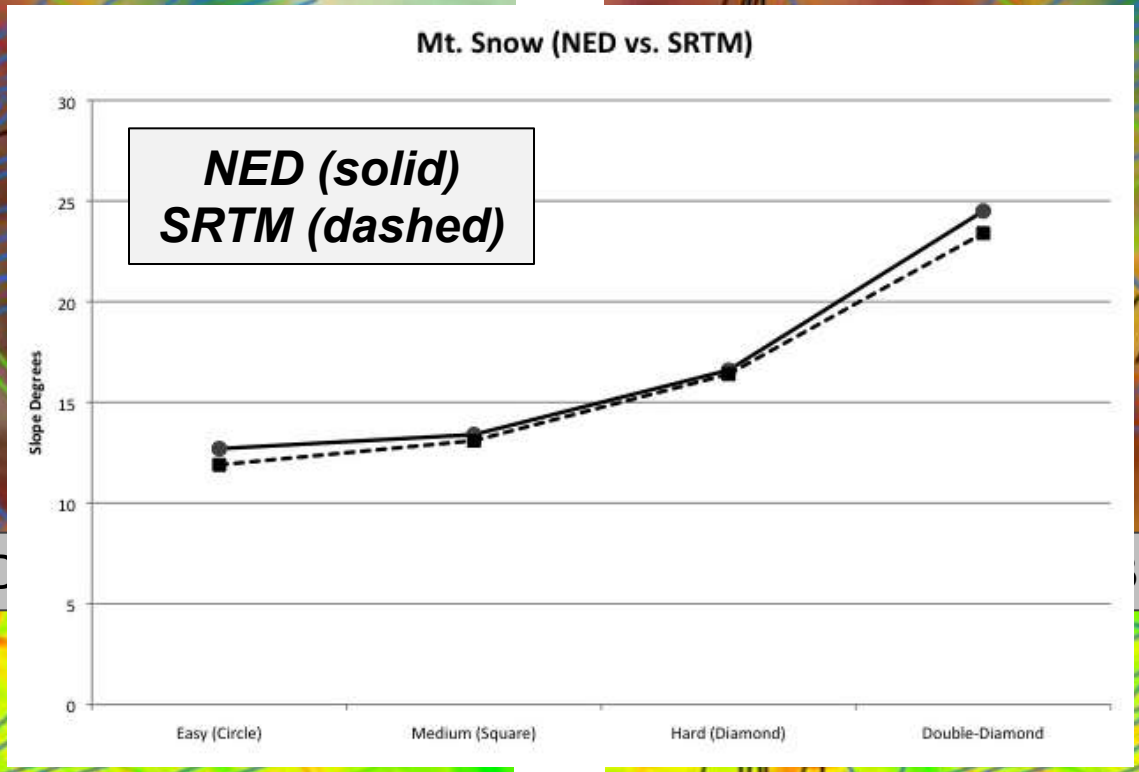
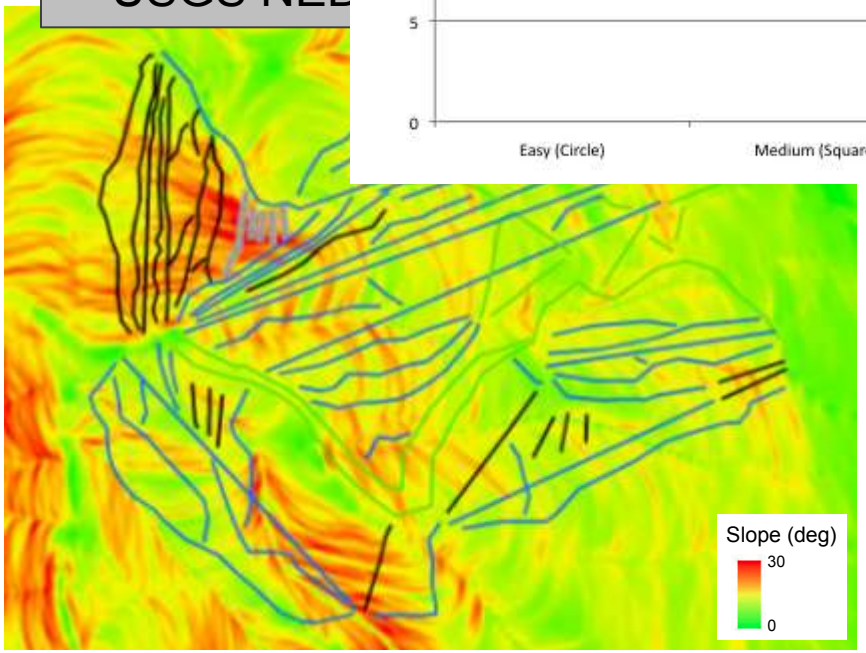


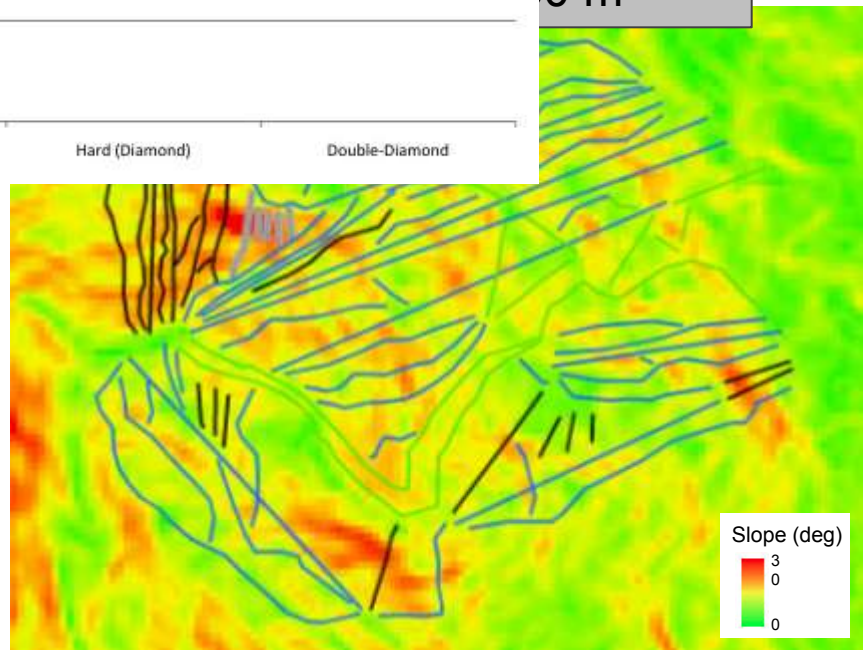


USGS NED

0 m







Student Example…

Slope assessment of the ski trails at Mad River Glen, Vermont

Thomas Sibley

Unexpected lower slopes overall are possibly due to being too liberal with trail areas and including slopes near the top and bottom of lifts. It may also be do to long, flatter runouts to the lifts for some trails that swing wider around the mountain. The very high maximum slopes for novice and intermediate trails are likely due to the problem of incorrectly calculating slopes for traverses where a flat, groomed, lower slope trail is actually made across hillslope or cut into it.

I made binary raster images for each level of trail difficulty and then ran zonal statistics on each raster. Due to this method, standard deviation is actually the standard deviation of each pixel (approx. 9m by 9m) for the level

	MEAN	MIN	MAX	STD DEV
Novice	15.62	6.08	35.93	4.70
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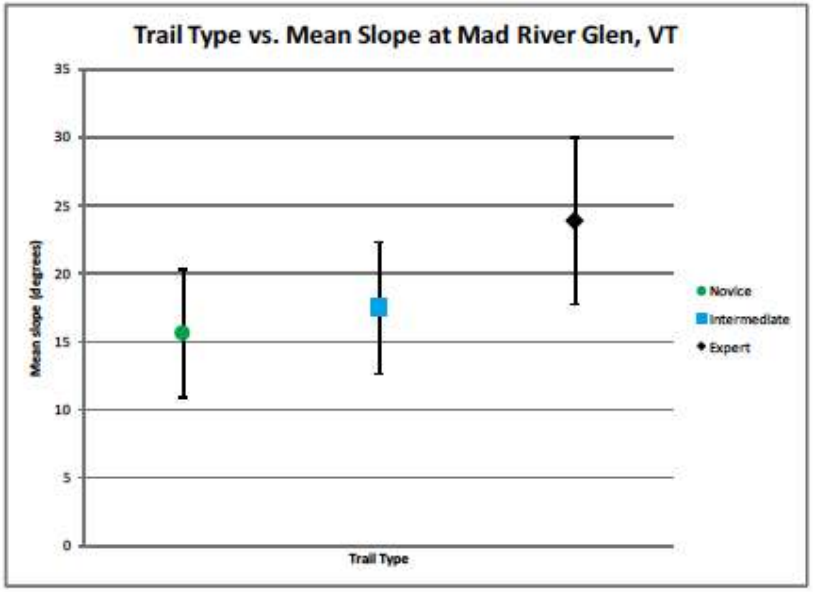
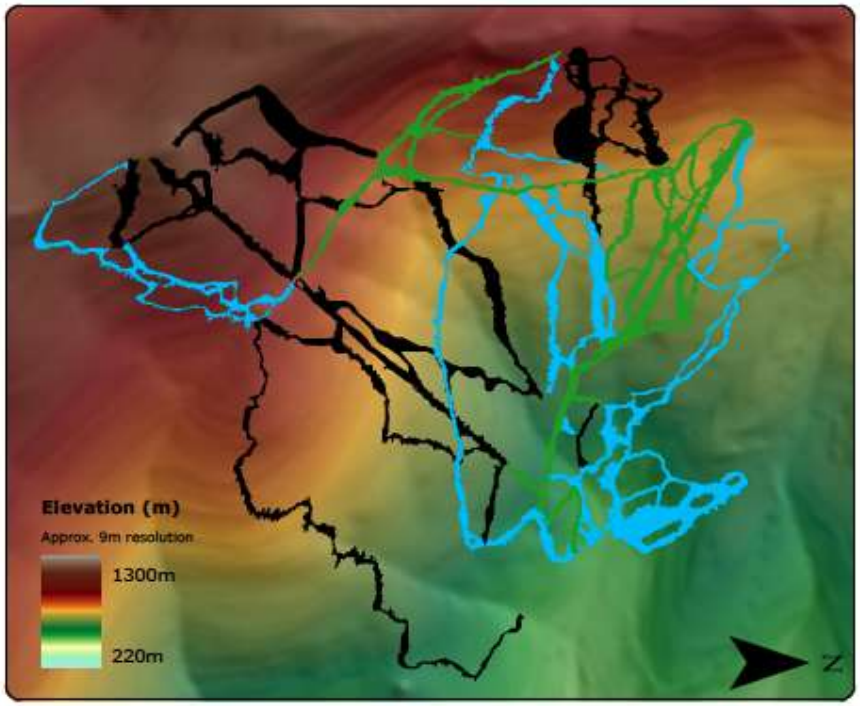
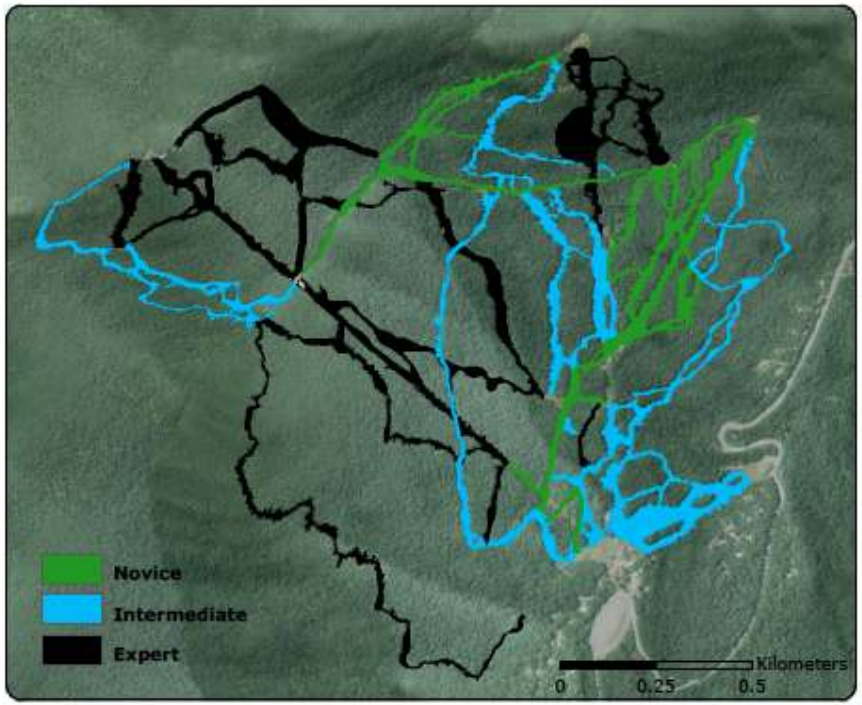


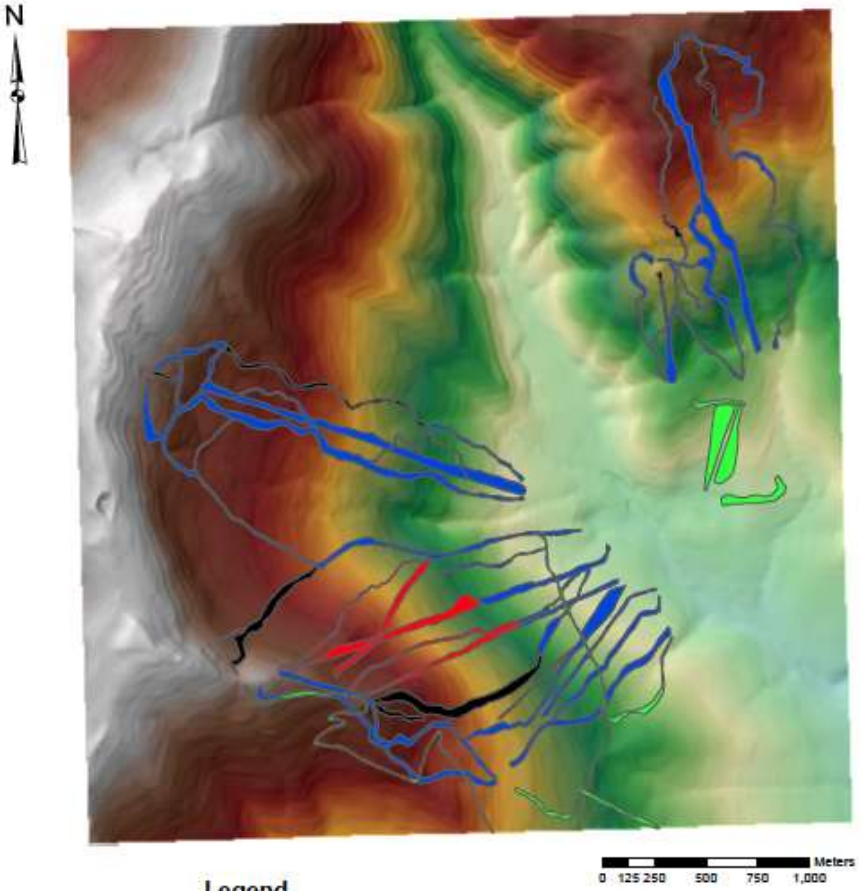




Student Example…

Ski Slopes at Stowe Mountain Resort, Vermont

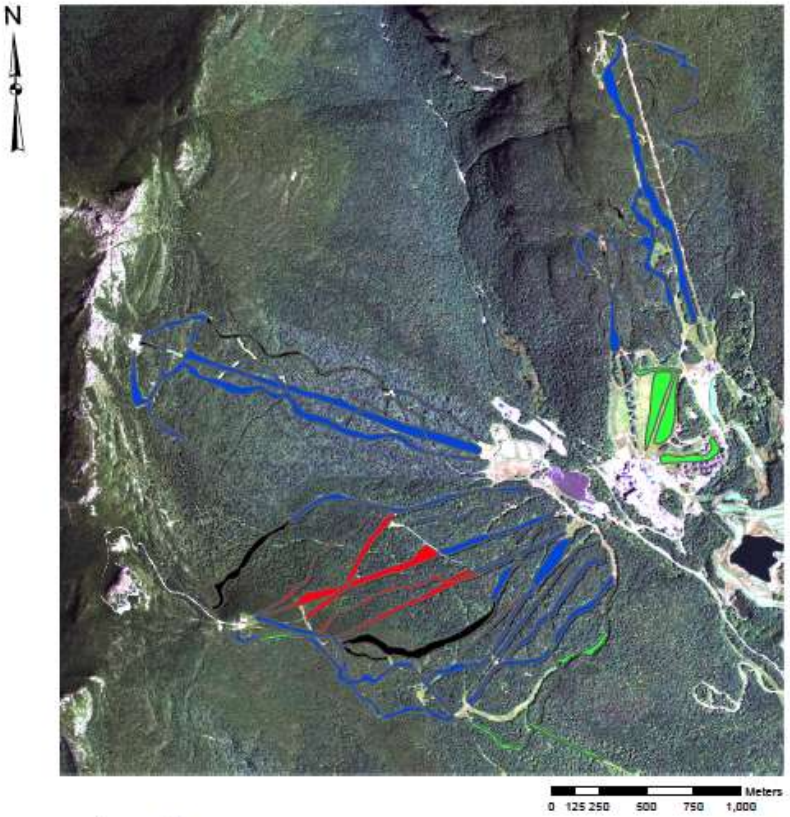
Background: Surface Topography



Legend

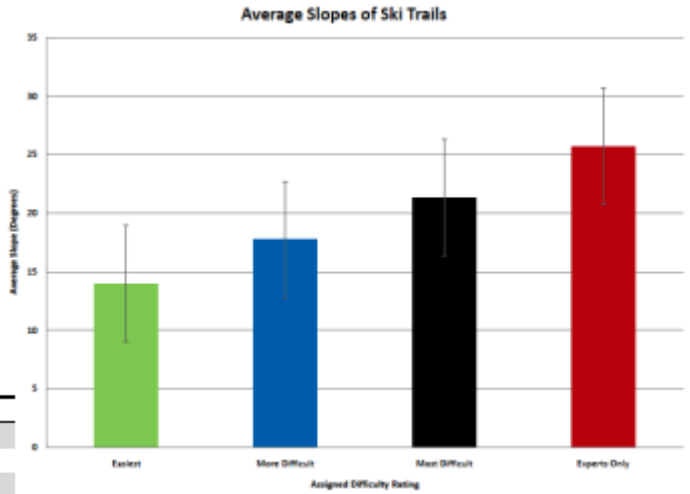
Topography
Value
High : 1338.08
Low : 405.363

Easiest
More_Difficult
Most_Difficult
Experts_Only



Legend

Easiest
More_Difficult
Most_Difficult
Experts_Only



Assigned Difficulty	Minimum Slope	Maximum Slope	Average Slope	Standard Deviation
Easiest	3.95329	32.3048	13.9713	4.38826
More Difficult	2.33096	45.5931	17.7388	5.68613
Most Difficult	3.9875	40.2998	21.3253	5.44968
Experts Only	12.6746	46.6433	25.7013	5.52678